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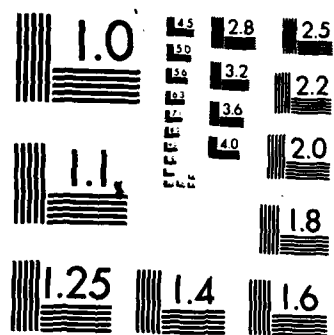
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19. ABSTRACT (Continue on reverse if necessary and identify by block number) This is a progress report of the Applied Mathematics Group in the Mathematics Department, Stanford University. This group began functioning officially on 1 September 1979, and is supported by the Office of Naval Research, the National Science Foundation, the Army Research Office, the Air Force Office of Scientific Research, and Stanford University. The personnel comprising this group during all or part of the reporting period are Joseph B. Keller, Professor of Mathematics, Stanford University; Russel E. Caflisch, Assistant Professor, Stanford University; John H. Maddocks, Acting Assistant Professor, Stanford University; Meira S. Falkovitz, Postdoctoral Fellow, Stanford University; Victor Twersky, Professor of Mathematics, University of Illinois, Chicago Circle; John G. Watson, Assistant Professor, University of Miami; Bernard A. Lippmann, Professor of Physics, Emeritus, New York University; Kevin C. Nunan, Graduate Student; Michael I. Weinstein, Postdoctoral Fellow, Stanford University; Stephanos Venakides, Assistant Professor, Stanford (CONTINUED)															
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ITEM #11, TITLE: PROGRESS REPORT, GRANT AFOSR-79-0134, SEPTEMBER 1, 1982 - APRIL 30, 1983.

ITEM #19, ABSTRACT, CONTINUED: University; Margaret Cheney, Research Associate, Stanford University; Graham Eatwell, Postdoctoral Fellow, Stanford University; Luis Lopez-Bonilla, Research Associate, Stanford University; James Geer, Professor of Mathematics, School of Advanced Studies, SUNY, Center at Binghamton, New York; Michael Reeken, Professor of Mathematics, University of Wuppertal, Germany; Erik Hansen, Professor of Mathematics, Technical University of Denmark, Lyngby. The various research activities of the members of this group are indicated by the list of publications contained in Section II. Abstracts or introductions from the papers produced during the report period are contained in Section III. In addition to the manuscripts already submitted, a number of projects are nearing completion. Thus Professor Keller, while at the Woods Hole Oceanographic Institute during the summer of 1982, studied the turbulent diffusion of a chemically reacting substance. Professor Keller and Dr. Falkovitz are completing a paper on Liesegang rings to account for the recent results of John Ross and his co-worker in the Chemistry Department at Stanford. Their theory uses the fourth order Cahn-Hilliard equation to describe diffusion. Dr. Eatwell is studying the propagation of an acoustic wave through a bubbly fluid, or through a medium containing resonant scatterers. Dr. Bonilla is studying the effective behavior of an elastic solid composed of randomly oriented crystallites. Mr. Nunan is calculating the effective viscosity of a suspension of rigid spherical particles in a viscous fluid and the effective elasticity of a lattice of rigid spheres in an elastic solid. Professors Geer and Keller are studying scattering of waves by thin bodies. In December 1982 Professor Keller was invited to deliver the Weizmann Lectures at the Weizmann Institute of Science in Rehovot, Israel. In March 1983 he presented an invited lecture at the British Theoretical Mechanics Colloquium in Manchester, England. In April 1983 he spent a week as Distinguished Visiting Professor of Mechanics and Applied Mathematics at Cornell University.

PROGRESS REPORT, Grant AFOSR-79-0134

September 1, 1982 - April 30, 1983

Applied Mathematics Group
Department of Mathematics
Stanford University

Principal Investigator: Joseph B. Keller



1. Introduction

This is a progress report of the Applied Mathematics Group in the Mathematics Department, Stanford University. This group began functioning officially on September 1, 1979, and is supported by:

1. Office of Naval Research;
2. National Science Foundation;
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5. Stanford University.

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The personnel comprising this group during all or part of the reporting period are:

1. Joseph B. Keller, Professor of Mathematics, Stanford University;
2. Russel E. Caflisch, Assistant Professor, Stanford University;
3. John H. Maddocks, Acting Assistant Professor, Stanford University;
4. Meira S. Falkovitz, Postdoctoral Fellow, Stanford University;
5. Victor Twersky, Professor of Mathematics, University of Illinois, Chicago Circle;
6. John G. Watson, Assistant Professor, University of Miami;

7. Bernard A. Lippmann, Professor of Physics, Emeritus, New York University;
8. Kevin C. Nunan, Graduate Student;
9. Michael I. Weinstein, Postdoctoral Fellow, Stanford University;
10. Stephanos Venakides, Assistant Professor, Stanford University;
11. Margaret Cheney, Research Associate, Stanford University;
12. Graham Eatwell, Postdoctoral Fellow, Stanford University;
13. Luis Lopez-Bonilla, Research Associate, Stanford University;
14. James Geer, Professor of Mathematics, School of Advanced Studies, SUNY, Center at Binghamton, New York.
15. Michael Reeken, Professor of Mathematics, University of Wuppertal, Germany.
16. Erik Hansen, Professor of Mathematics, Technical University of Denmark, Lyngby.

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11. RECENT PUBLICATIONS OF THE APPLIED MATHEMATICS GROUP

50. J. B. Keller Optimum inspection policies
Pub: Management Sci., 28, 447-450, 1982.
51. P. S. Hagan Travelling and stacked travelling wave solutions of parabolic equations
Pub: SIAM J. Math. Anal., 13, 717-738, 1982.
52. J.-M. Vanden-Broeck Contact problems involving the flow past an inflated aerofoil
Pub: J. Appl. Mech., 49, 263-265, 1982.
53. J.-M. Vanden-Broeck Nonlinear two-dimensional sail theory
Pub: Phys. Fluids, 25, 420-423, 1982.
55. P. S. Hagan Spiral waves in reaction diffusion equations
Pub: SIAM J. Appl. Math., 42, 762-786, 1982.
56. J.-M. Vanden-Broeck
J. B. Keller Parabolic approximations for ship waves and wave resistance
Pub: Proceedings of the Third International Conference on Numerical Ship Hydrodynamics, Paris, France, June 16-19, 1981.
57. A. Jeffrey
T. Kawahara Asymptotic Methods in Nonlinear Wave Problems
Pub: Pitman Publishing, Ltd., London, 1982.
58. M. J. Miksis
J.-M. Vanden-Broeck
J. B. Keller Rising Bubbles
Pub: J. Fluid Mech., 123, 31-42, 1982.
59. J. C. Neu Resonantly interacting waves
Pub: SIAM J. Appl. Math., 43, 1, 141-156, 1983.
60. J. B. Keller
M. J. Miksis Surface tension driven flows
Pub: SIAM J. Appl. Math., 43, 11, 268-277, 1983.
61. A. Jepson
A. Spence Folds in solutions of two parameter systems and their calculation: Part I
Pub: Stanford Univ. Numer. Anal. Report, 82-02.

62. J. B. Keller Time dependent queues
Pub: SIAM Rev., 24, 401-412, 1982.
63. R. E. Caflisch Shock profile solutions of the Boltzmann equation
B. Nicolaenko
Pub: Comm. Math. Phys., 86, 161-194, 1982.
64. P. S. Hagan Arrow's model of optimal pricing, use and
R. E. Caflisch exploration of undertain natural resources
J. B. Keller
Sub: Econometrica
65. R. E. Caflisch Radiation transport in a hot plasma
Acc: SIAM J. Appl. Math., in press.
66. J. B. Keller Jets rising and falling under gravity
J.-M. Vanden-Broeck
Pub: J. Fluid Mech., 124, 335-345, 1982.
67. R. E. Caflisch Fluid dynamics and the Boltzmann equation
Pub: Stud. Stat. Mech., 5, 194-223, 1983.
- 68.* M. S. Falkovitz Theory of periodic structures in lipid
M Seul bilayer membranes
H. L. Frisch
H. M. McConnell
Pub: Proc. Nat. Acad. Sci., 79, 3918, 1982.
69. R. E. Caflisch The fluid-dynamic limit of a model Boltzmann
equation in the presence of a shock
Pub: Institute National de Recherche en
Informatique et en Automatique, INRIA
No. 81, June 1981, 1-34.
70. P. F. Rhodes-Robinson On the short surface waves due to half-immersed
circular cylinder oscillating on water of
infinite depth
Pub: Proc. Royal Soc. London A, 384, 333-357, 1982.
71. P. F. Rhodes-Robinson Note on the reflexion of water waves at a
wall in the presence of surface tension
Pub: Math. Proc. Cambridge Philosophical Soc.,
92, 369-373, 1982.

*Not supported by AFOSR or ONR.

72. P. F. Rhodes-Robinson On the generation of water waves at an
inertial surface
Sub.
73. R. E. Caflisch Dynamic theory of suspensions with Brownian
G. C. Papanicolaou effects
Acc: SIAM J. Appl. Math., in press.
74. R. E. Caflisch Instability in settling of suspensions due
G. C. Papanicolaou to Brownian effects
Pub: Proceedings of conference Two-Phase Flow.
75. R. E. Caflisch Shock waves and the Boltzmann equation
B. Nicolaenko Acc: Proceedings NSF-AMS conference non-linear
PDE.
76. J. H. Maddocks Restricted quadratic forms and their application
to bifurcation and stability in constrained
variational principles
Sub: SIAM J. Appl. Math.
77. M. S. Falkovitz Spatially inhomogeneous polymerization in
L. A. Segel unstirred bulk
Pub: SIAM J. Appl. Math., 43, 386-416, 1983.
78. M. S. Falkovitz The scale of non-homogeneity as defined by
J. L. Frisch diffusion measurements
Pub: Journal of Membrane Science, 10, 61, 1982.
79. M. S. Falkovitz Optimal catalyst distribution in a membrane
H. L. Frisch Acc: Chem. Eng. Sci.
J. B. Keller
- 80.* M. S. Falkovitz Crawling of Worms
J. B. Keller Acc: J. Theor. Biol.
81. A. Jeffrey The random choice method and the free-surface
J. Mungai water profile after the collapse of a dam wall
Pub: Wave Motion, 4, 381-389, 1982.

*Not supported by AFOSR or ONR.

82. J. G. Watson
E. L. Reiss A statistical theory for imperfect bifurcation
Pub: SIAM J. Appl. Math., 42, 135-148, 1982.

83. J. G. Watson
J. B. Keller Reflection, scattering and absorption of acoustic
waves by rough surfaces
To be submitted.

84. M. I. Weinstein Global existence for a generalized Korteweg -
de Vries equation
Sub: SIAM J. Math. Anal.

85. M. I. Weinstein Nonlinear Schrödinger equations and sharp
interpolation estimates
Pub: Commun. Math. Phys., 87, 567-576, 1983.

86. M. Cheney Two-dimensional scattering: the number of
bound states from scattering data
Sub: J. of Math. Phys.

87. L. L. Bonilla
A. Liñán Relaxation oscillations, pulses, and travelling
waves in the diffusive Volterra delay-differential
equation
Acc: SIAM J. of Appl. Math., in press.

88. P. F. Rhodes-Robinson Note on the effect of surface tension on water
waves at an inertial surface
Pub: J. Fluid Mech., 125, 375-377, 1982.

89. J. B. Keller
J. Hunter Weak shock diffraction
Acc: Wave Motion, in press.

90. J. B. Keller
J. Hunter Weakly nonlinear high frequency waves
Acc: Comm. Pure and Appl. Math., in press.

91. J. B. Keller
J. C. Neu Asymptotic analysis of a viscous Cochlear model
Sub: J.A.S.A.

92. J. B. Keller
J.-H. Vanden-Broeck Parabolic approximations for ship waves and wave
resistance
Pub: Proc. 3rd Intl. Conf. on Numerical Ship
Hydrodynamics, Paris, France, June 16-19, 1981.

93. A. Spence
A. Jepson The numerical computation of turning points of
nonlinear equations
Pub: Treatment of Integral Equations by Numerical
Methods, 169-183, London, 1982.
94. J. B. Keller
R. Burridge Biot's poroelasticity equations by homogenization
Pub: Springer Lecture Notes, in Macroscopic
Properties of Disordered Media, NY, 51-57, 1982.
95. J. B. Keller Capillary waves on a vertical jet
Acc: J. Fluid Mech., in press.
96. J. B. Keller
A. S. Whittemore Survival estimation using censored data
Sub: J. Royal Statist. Soc., Series B
97. J. B. Keller
J. F. Geer Eigenvalues of slender cavities and waves in
slender tubes
To be submitted.
98. J. B. Keller
R. Voronka Valuation of stocks and options
To be submitted.

1. Dynamic theory of suspensions with Brownian effects, by R. E. Caflisch and G. C. Papanicolaou.

We consider a suspension of particles in a fluid settling under the influence of gravity and dispersing by Brownian motion. A mathematical description is provided by the Stokes equations and a Fokker-Planck equation for the one-particle phase space density. This is a nonlinear system that depends on a number of parametric functions of the spatial concentration of the particles. These functions are known only empirically or for dilute suspensions. We analyze the system, its stability, its asymptotic behavior under different scalings and its validity from a more microscopic description.

2. Two-dimensional scattering: the number of bound states from scattering data, (a), by M. Cheney.

Relations are found between scattering data and the spectrum for the two-dimensional Schrödinger operator $\Delta + V(x)$, where V is a local noncentral potential. In particular a two-dimensional version of the Levinson theorem is obtained; this theorem gives the number of bound states in terms of the change in phase of the determinant of the scattering operator.

3. Shock profile solutions of the Fokker-Planck equation, by R. L. Geller and B. Nicolaenko.

Shock waves in gas dynamics can be described by the Euler-Maxwell system, or Boltzmann equations. We prove the existence of shock profile solutions of the Boltzmann equation for shocks which are weak. The shock is written as a truncated expansion in powers of the shock strength, the first two terms of which come exactly from the Taylor (sinh(x)) profile for the high-order solution. The full solution is found by a projection method like the Liapunov-Schmidt method as a bifurcation from the constant state in which the bifurcation parameter is the difference between the speed of sound c_0 and the shock speed s .

4. Restricted quadratic forms and their application to bifurcation and stability in constrained variational principles, by J. H. Maddocks.

The subjects of this investigation are the abstract properties and applications of *restricted quadratic forms*. The first part of the presentation resolves the following question: If L is a self-adjoint linear operator mapping a Hilbert space H into itself, and S is a subspace of H , when is the quadratic form $\langle u, Lu \rangle$ positive for any non-zero $u \in S$? In the second part of the presentation, restricted quadratic forms are further examined in the specific context of constrained variational principles; and the general theory is applied to obtain information on stability and bifurcation. Two examples are then solved: one is finite-dimensional and of an illustrative nature; the other is a longstanding problem in elasticity concerning the stability of a buckled rod. In addition to being a valuable analytical tool for isoperimetric problems in the calculus of variations, the tests described are amenable to numerical treatment. A theorem concerning the variational characterization of eigenvalues is also obtained.

5. Spatially inhomogeneous polymerization in unstirred bulk, by H. S. Othavitz and L. A. Segel.

A new experimental method for the formation of large polymers of very

narrow molecular weight distribution is examined theoretically. The problem belongs to the general class of transport-reaction problems in multi-component media. A comprehensive mathematical model of the phenomenon is presented. Noteworthy is the fact that diffusive fluxes are decomposed into two parts, pure diffusion and back-bulk-flow. It is shown that the full problem, which consists of an infinite number of coupled nonlinear differential equations, can be reduced to two such equations. Heat production is also considered in an auxiliary investigation. The appropriate differential equations are solved numerically and the physical significance of the results is discussed.

6. The scale of non-homogeneity as defined by diffusion measurements, by M. S. Falkovitz and H. L. Frisch.

The asymptotic behaviour of the permeation rate in non-homogeneous laminar slabs of increasing width ℓ is studied. We show rigorously that for a wide class of slabs with non-homogeneities distributed in a statistically homogeneous manner, the permeation rate approaches that of a homogeneous slab as $1/\ell^2$. The result is compared with previous studies of this subject.

7. Crawling of worms, by J. B. Keller and M. S. Falkovitz.

The mechanics of a worm crawling along a flat surface is analyzed. The external forces of friction and gravity, and the internal pressure and tension, are taken into account. An equation of motion is formulated, and solutions are sought in which both the tension and the linear density are required to lie between prescribed bounds. Pulse and periodic travelling wave solutions are constructed. The maximum crawling velocity is determined, as well as the wave form which achieves it. Comparison of the results with experimental observations shows that the theory yields a maximum crawling velocity which is much larger than the observed velocity. Therefore the theory was changed to require that the time rate of change of tension be less than a prescribed bound, rather than

that the function be bounded. With this modification, the theory agrees fairly well with the observations.

8. The random choice method and the free-surface water profile after the collapse of a dam wall, by A. Jeffrey and J. Beungi.

The random choice (RC) method due to Glimm [1], subsequently modified by Chorin [2] and Sod [3], is applied to the shallow water equations of Stoker [4], in order to determine the free-surface profile of water, as a function of position and time, when a dam wall suddenly collapses. The numerical results obtained by this method are compared with the analytical results due to Stoker for this classical problem [5], and with numerical results obtained by a further modification of the Glimm-Chorin scheme involving a smoothing operation. The improvement brought about by the smoothing, and the generally close agreement with the exact result that is then obtained, is a feature of this modified approach.

9. A statistical theory for imperfect bifurcation, by J. G. Watson and E. L. Reiss.

An "honest" statistical method is presented to analyze the effects of imperfections, and other disturbances on the bifurcation of solutions of non-linear problems. First, uniformly valid asymptotic approximations of the solutions are obtained for any realization of the imperfections. The approximations are valid as the magnitude of the imperfections approaches zero. The statistical properties of the solutions are then deduced directly from these approximations, for specified statistics of the imperfections. For simplicity of presentation, the imperfections are taken as zero-mean, wide-sense stationary, Gaussian random processes. The statistical analysis is elementary. It provides easily analyzed results for the expected values and variances of the solutions. Confidence limits are also given.

10. Global existence for a generalized Korteweg - de Vries equation, by M. Weinstein.

A sufficient condition for global existence is obtained for the generalized Korteweg - de Vries Equation (GKdV) $u_t + u^3 u_x + u_{xxx} = 0$, $x \in \mathbb{R}^1$, $t \in \mathbb{R}^+$. This condition is expressed in terms of the solitary (traveling) wave solution of GKdV.

11. Nonlinear Schrödinger equations and sharp interpolation estimates, by M. I. Weinstein.

A sharp sufficient condition for global existence is obtained for the nonlinear Schrödinger equation

$$(NLS) \quad 2i\phi_t + \Delta\phi + |\phi|^{2\sigma}\phi = 0, \quad x \in \mathbb{R}^N, \quad t \in \mathbb{R}^+,$$

in the case $\sigma = 2/N$. This condition is in terms of an exact stationary solution (nonlinear ground state) of (NLS). It is derived by solving a variational problem to obtain the "best constant" for classical interpolation estimates of Nirenberg and Gagliardo.

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